CW370 USER MANUAL

Table of Contents

Dynamic Light Scattering Theory

Introduction

In recent years, the technique of dynamic light scattering (DLS) -- also called quasi-elastic light scattering (QELS) or photon correlation spectroscopy (PCS) -- has proven to be an invaluable -analytical tool for characterizing the size distribution of particles suspended in a solvent (usually water). The useful size range for the DLS technique is quite large -from below 5 am (0.005 micron) to several microns. The power of the technology is most apparent when applied to the difficult Particularly for diameters below 300 nm submicron size range, where most competing measurement techniques lose their effectiveness or fail altogether. Consequently, DLS-based sizing instruments have been used extensively to characterize a wide range of particulate systems, including synthetic polymers (e.g. latexes, PVCs, etc.), oil-in-water and water-in-oil emulsions, vesicles, micelles, biological macromolecules, pigments, dyes, silicas, metallic sols, ceramics and numerous other colloidal suspensions and dispersions.

As we shall see, the DLS technique possesses a number of unique characteristics, which make it a powerful and effective tool for particle size analysis in the submicron region. Precisely because of the nature of some of these characteristics, a DLS instrument behaves like no other competing technology. Often, it will yield results of great accuracy, with excellent reproducibility. At other times, the results may be substantially distorted, and even misleading. In short, the "rules of the game" by which a DLS instrument operates result not only in distinct advantages, but also in potentially serious shortcomings, or pitfalls. It is the purpose of this section to provide insight into the scientific rationale for this technique, in general, and the NICOMP 370, in particular. In so doing, we hope to help maximize the use of the 370 and to become better prepared to ask the right kinds of questions whenever unexpected results occur. Our philosophy -- keep it simple! We have no intention of intimidating with a rigorous discussion of the physical principles of coherent light scattering or the detailed mathematics of Laplace transform inversion -- both of which figure prominently in the NICOMP 370. However, we do feel it useful to provide a reasonable review of the principles underlying the DLS technique. For the weak of heart -- skip directly to the section, The Simplest Approach to Size Distribution Analysis: Gaussian Analysis.

The Simplest Approach to Size Distributions: Gaussian Analysis

We shall see that two very different mathematical procedures, or "algorithms", have been developed to analyze the autocorrelation "raw data", C(t'), depending on the nature of the underlying particle size distribution. The Model 370 automatically selects the more appropriate of the two analysis procedures and provides the user with a running measure of the accuracy, or "goodness of fit", of the computed distribution resulting from the particular analysis chosen. Nevertheless, we feel it essential to gain an appreciation of the rationale behind each of the analysis methods and to become comfortable with some typical results obtained for actual particle systems. The latter can be studied in a controlled, accurate way using polystyrene latexes, oil-in-water emulsions and other well-characterized materials.

Broad unimodal distribution -- Gaussian Analysis

Following the discussion in the previous section, it is now obvious that a mixture of particle sizes must give rise to an autocorrelation function C(t') which decaying exponential function is *no longer* a simple i.e. having a single, well-defined decay time constant τ, as shown in Figure 8c. The existence of more than one rate of diffusion must necessarily give rise to a mixture of decaying exponential functions, each of which has a different time decay constant τ_i, corresponding to a particular diffusivity D_i and, hence, of particle radius R_i. The challenge which we face is to develop fast and efficient mathematical methods of analysis, whereby we can "deconvolve" C(t') and thereby extract the distribution of D values (and hence of particle diameters) from the detailed shape of C(t'). The "magic" behind the Model 370 has to do with its ability to obtain, accurately and consistently, the most useful information relating to the distribution of particle sizes in solution. To do this, the 370 must analyze precisely the deviations of autocorrelation function C(t') from single-exponential behavior. As we shall discover below, these deviations are often surprisingly slight and subtle, given the large range of complicated distributions which are encountered.

Dynamic Light Scattering Theory

The Simplest Approach to Size Distributions: Gaussian Analysis

The simplest kind of complexity in the particle size distribution which we can introduce is a smooth, gaussian-like population of sizes, having a well-defined mean diameter and half width. Such an idealized distribution shape is often obtained for *emulsions*, prepared by a variety of processes, sonication, homogenization and microfluidization™. Typically, some type of oil and water are caused to be mixed together with the aid of a dispersing agent (e.g. a non-ionic surfactant) to form a single, microscopically homogeneous phase. The result: tiny droplets of one component (e.g. the oil) suspended in the other component, or "phase" (e.g. water). The mean size and width of the resulting droplet distribution are usually sensitive functions of the stoichiometry of the starting compounds and the duration and detailed nature of the preparation technique employed. In Figure 9a we show the autocorrelation function for a fat emulsion, used for intravenous ("IV") feeding. The channel width used here was 21 usec.

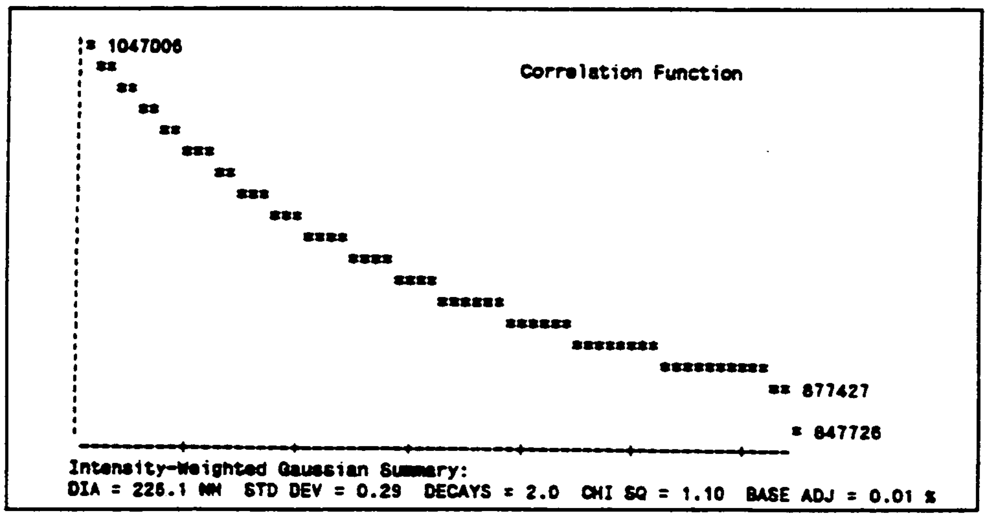

Figure 9a: Autocorrelation function for an IV fat emulsion.

Let us make a visual comparison between Figure 9a and 8a, obtained for the narrow 91 nm latex standard. The shapes of the two decaying curves appear to be quite similar, which is somewhat surprising given the differences between the two samples. Qualitatively, we conclude that the average, or characteristic, particle diameter associated with Figure 9a must be roughly twice that associated with Figure 8a. The reason: both curves possess about the same number of "decays" in falling to the 64th channel, and the channel width for the latter sample is *twice* that of the former.